FIN42020 Derivative Securities Assessment Submission Form

GROUP 27			
Student Name	**Student Number (id card)**	**Total Peer Mark (/30)**	**e - Signatures:**
Karl Grogan	**20204532**	**30**	Karl Grogan
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Vipul Andrew Monterio	**24201500**	**30**	Vipul Andrew Monterio
Aditya Suhane	**24212188**	**30**	Aditya Suhane

Signatures:

Signed - Karl Grogan   Date – 04th December 2024

Signed- Rhea Mathews Date - 04th December 2024

Signed- Vipul Andrew Monterio Date - 04th December 2024

Signed- Aditya Suhane Date - 04th December 2024

Evaluator	**Evaluatee**	Peer Mark Effort (/10)	Peer Attitude (/10)	Peer Contribution (/10)	Total Peer Mark (/30)
1.Karl Grogan	1. Rhea Mathews	10	10	10	30
2. Aditya Suhane	1. Rhea Mathews	10	10	10	30
3. Vipul Monteiro	1. Rhea Mathews	10	10	10	30
				Total Average:	30
1. Karl Grogan	2. Aditya Suhane	10	10	10	30
2. Rhea Mathews	2. Aditya Suhane	10	10	10	30
3. Vipul Monteiro	2. Aditya Suhane	10	10	10	30
				Total Average:	30
1.Karl Grogan	3. Vipul Monteiro	10	10	10	30
2. Aditya Suhane	3. Vipul Monteiro	10	10	10	30
3. Rhea Mathews	3. Vipul Monteiro	10	10	10	30
				Total Average:	30
1. Rhea Mathews	4. Karl Grogan	10	10	10	30
2. Vipul Monteiro	4.Karl Grogan	10	10	10	30
3. Aditya Suhane	4. Karl Grogan	10	10	10	30
				Total Average:	30

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Introduction

This report investigates option pricing and hedging strategies based on WBA stock. This report takes the reader through explanations of implied volatility, put-call parity, delta hedging, and volatility spreads.

1.Put Call Parity

Put-Call Parity is a fundamental concept in finance that defines the relationship between European call and put options sharing the same expiration date and strike price. If Put-Call Parity does not hold this gives rise to arbitrage opportunities.

The Put-Call parity equation is expressed as follows:

$$\boldsymbol{S + P = C + Ke^{-rT}}$$

Where:

- S: Stock price as of November 5th
- P: Last traded price of the put option
- C: Last traded price of the call option
- K: Strike price of the option
- r: Risk-free rate (4.70% - taken average of Treasury bill from Nov 5th to 15th - Market Yield on U.S. Treasury Securities at 1-Month Constant Maturity, Quoted on an Investment Basis (DGS1MO) | FRED | St. Louis Fed)
- T: Time to expiration, calculated as (Expiry date−Trade date)/252(Trading Days)
- e^{-rt}: Discount factor for the strike price over time

The Put-Call Parity relationship, for European options, states that a portfolio containing one put option and the underlying stock is equal in value to a portfolio comprising one call option and the present value of the strike price. When this balance is disrupted, it creates arbitrage opportunities enabling traders to capitalize and earn riskless profits.

Table1: For Arbitrage Strategy

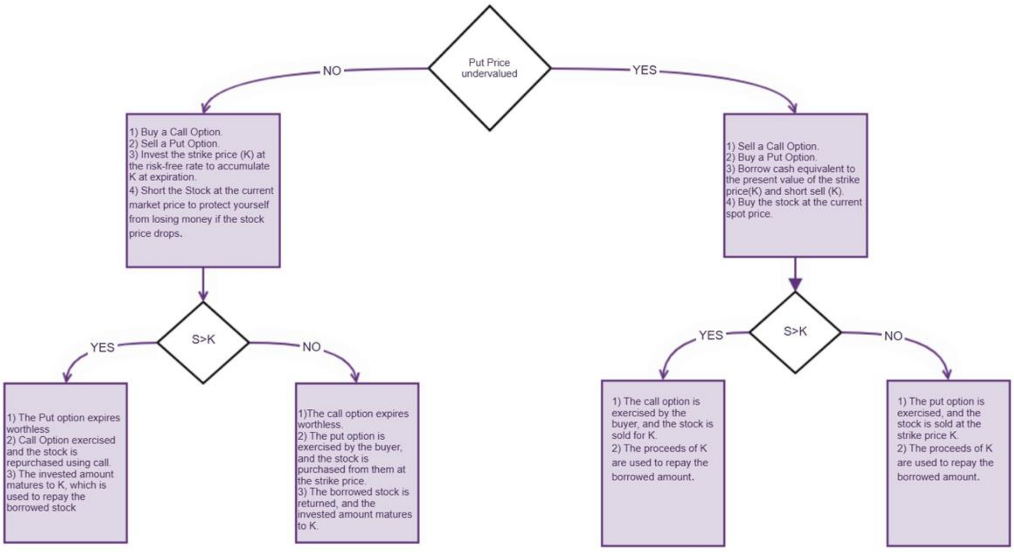
Stock Price	Strike Price	Risk-Free Rate	(t)=Time to Maturity (9 Trading days/252 Trading days)	S+P	C+K*e^-rt	Fair Price of Put option P=C+K*e^-rt-S	Arbitrage Strategy
9.62	7.5	0.05	0.04	9.64	9.44	-0.18	Premium of Put is Overvalued Select Equation 1
9.62	8.5	0.05	0.04	9.67	9.55	-0.07	Premium of Put is Overvalued Select Equation 1
9.62	9	0.05	0.04	9.74	9.63	0.01	Premium of Put is Overvalued

							Select Equation 1
9.62	9.5	0.05	0.04	9.92	9.88	0.26	Premium of Put is Overvalued Select Equation 1
9.62	10	0.05	0.04	10.18	10.19	0.57	Premium of Put is Undervalued Select Equation 2
9.62	10.5	0.05	0.04	10.66	10.55	0.93	Premium of Put is Overvalued Select Equation 1
9.62	11	0.05	0.04	11.34	11.00	1.38	Premium of Put is Overvalued Select Equation 1

From the table above the reader will see that Put-Call Parity has been violated enabling an investor to lock in riskless profits.

If $\boldsymbol{S+P > C+ Ke^{-rT}}$ *(Equation 1)*, an investor would buy a call, sell a put, and short the stock or lend money (at risk-free rate).

If $\boldsymbol{S+P < C+ Ke^{-rT}}$ *(Equation 2)*, trader could buy a put, sell a call, buy the stock or borrow money (at risk-free rate).



The flowchart serves as a visual representation of arbitrage strategies based on violations of Put-Call Parity. Two scenarios outlined below are:

- For overvalued put options $\boldsymbol{S+P > C+Ke^{-r(T-t)}}$ *(Equation 1)*: The strategy focuses on taking advantage of the overpricing by creating a synthetic equivalent portfolio. The invested amount and hedged stock position protect the trader from adverse price movements, ensuring profitability regardless of the stock's final price relative to K.

- For undervalued put options $\boldsymbol{S+P < C+Ke^{-r(T-t)}}$ *(Equation 2)*: The approach exploits undervaluation by forming a portfolio that capitalizes on the pricing discrepancy. Borrowing and short selling create an arbitrage opportunity where proceeds from option exercises and stock transactions repay borrowed amounts while locking in a profit.

Estimate Risk:

The inputs and assumptions that could affect the reliability of the results and the success of the arbitrage opportunity include:

- Risk-Free Assumption(r): Using a constant or an average risk-free rate might not reflect the actual rates during the options lifetime, leading to discrepancies in the parity option.
- Time to Expiration(t): Small errors in calculating the remaining time to expiration could distort the discounting factor for the strike price which affects the theoretical pricing.
- Transaction Costs: Estimates often assume no transaction costs but in the real market there are various costs such as commissions, bid-ask spreads which could reduce the profits or eliminate it.
- Liquidity: The analysis might assume high market liquidity but illiquidity in the options can make it difficult to implement the strategy effectively.
- Model Limitations: The parity equation assumes European style options and a perfect market environment, if the options are an American style option or the market has inefficiencies, the results may not hold.

Identifying and acknowledging the above risks ensures that the analysis is robust and reflects real-world trading conditions, without addressing these risks, the estimates could lead to incorrect conclusions about the existence of profitability of arbitrage opportunities

2. Implied Volatility

The market's anticipation of future price volatility for an asset is measured by Implied Volatility (IV). Traders usually look at implied volatility for pricing options, as it is forward-looking compared to normal volatility, which is backward-looking. Implied volatility is mainly. In the case of normal volatility, it is based on changes in price movements and is calculated using the standard deviation of asset prices. However, implied volatility considers various factors while being calculated, which is why it is called forward-looking. It also has a one-to-one correspondence with price, meaning higher prices directly correspond to higher implied volatility, using models like the Black-Scholes Model we have calculated the option's pricing and represents the expected size of price changes in the underlying asset during the course of the option.

Black-Scholes Formula: The Black-Scholes formula is a cornerstone of modern finance which is widely employed in the valuation of options and is used by Traders, Portfolio Managers to make informed decisions.

IV is a key application of the Black-Scholes formula since it cannot be directly observed, the formula helps to derive it from the market price of an option at the specific strike price and expiration date.

Formula:

Call Option Formula: $C = S \cdot N(d^1) - K \cdot e^{-r(T-t)} \cdot N(d^2)$

The formula for pricing a put option is:

$$P = K \cdot e^{-r(T-t)} \cdot N(-d^2) - S \cdot N(-d^1)$$

The terms d_1 and d_2 are defined as:

$$d^1 = \frac{\left[\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{}2\right)(T-t)\right]}{}\left(\sigma\sqrt{T-t}\right)$$

$$d^2 = d^1 - \sigma\sqrt{T-t}$$

Here

- C: Price of the call option
- P: Price of the put option
- S: Current price of the underlying asset
- K: Strike price of the option
- T-t: Time to expiration
- r: Risk-free interest rate
- σ: Volatility of the underlying asset
- N(d): Cumulative distribution function of the standard normal distribution

Methodology to obtain Implied Volatility:

The implied volatility (IV) for options data as of 5th November 2024 was obtained using a single methodology, calculating theoretical option prices based on the Black-Scholes model and refining the results with the Goal Seek function in Excel. Since IV is not directly observable, it was derived by matching the theoretical price of the option to its traded market price. After taking into consideration the inputs such as strike price, market price, risk-free interest rate, time to maturity and option traded mid-price. We considered the IV estimate of 20% prior to using the Goal Seek function. We calculated theoretical prices based on Black-Scholes formula and incorporated a column to include difference between theoretical and traded prices. To calculate IV, we then used the Goal Seek function, iteratively adjusting the IV value until the theoretical price aligned perfectly with the trading price reducing the difference of theoretical and traded prices to zero. The goal Seek function ensured accuracy and provided an efficient approach to calculate IV

Result:

Table 2: Goal Seek result for Call Option

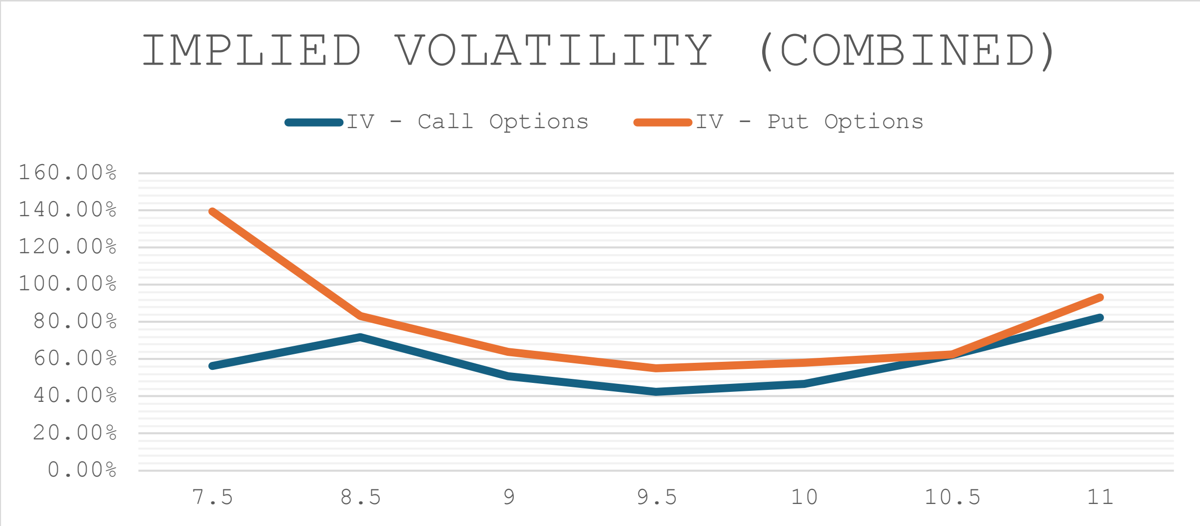
Calls										
Ticker	**K/Strike**	**Mid-Price**	**S=Stock Price**	**r=Risk-Free Rate**	**D1**	**D2**	**Theoretical Call**	**Implied volatility (Bloomberg)**	**Implied Volatility (Calculated)**	**Difference Between Theoretical and traded price**
WBA 11/15/24 C7.5	7.5	1.63	9.62	4.6975%	0.31	0.21	1.64	0.00%	56.47%	0.00
WBA 11/15/24 C8.5	8.5	1.11	9.62	4.6975%	0.20	0.06	1.11	56.41%	72.02%	0.00
WBA 11/15/24 C9	9	0.69	9.62	4.6975%	0.13	0.03	0.69	52.13%	50.99%	0.00
WBA 11/15/24 C9.5	9.5	0.375	9.62	4.6975%	0.07	-0.006	0.37	50.66%	42.42%	0.00
WBA 11/15/24 C10	10	0.16	9.62	4.6975%	0.02	-0.06	0.16	48.92%	46.54%	0.00
WBA 11/15/24 C10.5	10.5	0.06	9.62	4.6975%	-0.01	-0.13	0.06	49.37%	62.36%	0.00
WBA 11/15/24 C11	11	0.02	9.62	4.6975%	-0.04	-0.20	0.01	48.69%	82.36%	0.00

Table 3: Goal Seek result for Put Option

Put										
Ticker	**K/Strike**	**Mid-Price**	**S=Stock Price**	**r=Risk-Free Rate**	**D1**	**D2**	**Theoretical Put**	**Implied volatility (Bloomberg)**	**Implied Volatility (Calculated)**	**Difference Between Theoretical and traded price**
WBA 11/15/24 P7.5	7.5	0.01	9.62	4.6975%	0.38	0.12	0.01	74.62%	139.47%	0.00
WBA 11/15/24 P8.5	8.5	0.05	9.62	4.6975%	0.21	0.05	0.05	56.78%	83.12%	0.00
WBA 11/15/24 P9	9	0.15	9.62	4.6975%	0.14	0.02	0.15	55.26%	64.01%	0.00
WBA 11/15/24 P9.5	9.5	0.33	9.62	4.6975%	0.08	-0.02	0.33	53.23%	55.09%	0.00
WBA 11/15/24 P10	10	0.61	9.62	4.6975%	0.03	-0.07	0.61	50.84%	58.23%	0.00

WBA 11/15/24 P10.5	10.5	0.92	9.62	4.6975%	-0.01	-0.13	0.92	0.00%	62.70%	0.00
WBA 11/15/24 P11	11	1.46	9.62	4.6975%	-0.03	-0.21	1.46	50.51%	93.16%	0.00

Figure 1: Implied Volatility Graph for Call and Put Option



In the above two plots, there is a volatility smile curve for both the call option and the put option. A volatility smile is a plot of implied volatility against strike prices. In the case of the put option, marked in orange, it shows a perfect smile curve. From the graph, it is clearly stated that the at-the-money call is at the lowest point of the curve, meaning the implied volatility at this stage is the lowest. Compared to out-of-the-money puts, the implied volatility tends to get higher, and similarly, in the case of in-the-money options, the implied volatility also tends to increase.

In the case of the call option, the implied volatility is again the lowest at the at-the-money option and increases for both out-of-the-money puts and in-the-money puts. Also, in both cases, the volatility is downward-sloping when it is high and upward-sloping when it is low. This is due to mean reversion, as there is some long-term level of volatility for an individual asset to which the market will return.

There is also some inconsistency in the implied volatility, as many factors can affect this interpretation. In the first part, we observe put call parity, which is a major factor for this. Additionally, WBA has not been performing well in the past couple of years, with stock prices plummeting in the past couple of days. This can be a major sign of uncertainty in investors' minds, implying negative sentiment toward WBA. Moreover, implied volatility also affects market sentiments.

3. Delta Hedging

The goal of hedging is to reduce risk as much as possible. Delta hedging is an options trading strategy an investor uses to reduce the exposure to price changes in the underlying asset. When the price of the option fluctuates due to changes in the underlying asset price, the associated risk can be mitigated by adjusting the position in the underlying stock. The delta value is a measure of how much of the underlying asset the investor should hold. Unlike static hedging strategies, delta hedging is a dynamic, meaning that the delta changes over time requiring the investor to adjust or “rebalance” their position to remain “delta-neutral”.

Methodology to obtain Delta hedging:

Outlined below is the team's approach to executing a delta hedging strategy, utilizing both 22-day historical volatility and implied volatility.

Table 4: Delta Hedging Parameters

Time to expiry (in years)	15th November
D1	D1 represents how likely the option will end up in the money by expiry, considering the asset price, strike price, volatility, time and interest rate. It represents the normal distribution used to calculate option prices Formula $$\boldsymbol{d1} = \frac{\left(\ln\left(\frac{So}{k}\right) + \left(r + \frac{\sigma^2}{2}\right)T\right)}{\left(\sigma\sqrt{T}\right)}$$
Delta	Delta of a stock option is the ratio of change in price of the stock option to change in the price of the underlying stock. It is the number of units of the stock we should hold for each option shorted in order to create a riskless portfolio. $$\Delta Call = N(d1)$$
Shares bought/(Sold)	We adjusted the portfolio by buying or selling shares as the stock price and delta changed to stay delta-neutral.
Cost of shares	Cost paid/received to buy or sell the shares required to hedge the option position.
Cumulative cost including interest	Cumulative cost as of previous trading date + Cost of shares as of that date + Interest cost

Interest cost	Shares were borrowed at a 4.7% interest rate to maintain the portfolio. When fewer shares were required, some were sold to reduce the borrowing amount, which in turn lowered the overall interest expenses on the borrowed funds.

Delta Hedging using Implied Volatility:

Table 5: Delta Hedging using Calculated Implied Volatility

Contract symbol	WBA241115C00009500
	10 (Assumed)
Short call options	1000 (Assumed)
Interest rate	4.70%
Strike Price	9.5
Implied Volatility	42.42% (Taking it as Constant)

Table 6: Results for Delta Hedging using Calculated Implied Volatility

Trade Date	**Stock Price**	**Time to expiry (in years)**	**Delta**	**Shares owned**	**Shares bought/(Sold)**	**Cost of shares**	**Cumulative cost including interest**	**Interest cost**	**PV calculation for my cost including interest**
5th November	9.62	0.0317	0.59	588.47	588.47	5661.06	5661.06	1.06	5661.06
6th November	9.23	0.0278	0.36	361.66	-226.81	-2093.45	3568.67	0.67	3408.55
7th November	9.27	0.0238	0.37	372.73	11.07	102.64	3671.97	0.68	3507.22
8th November	9.07	0.0198	0.23	232.77	-139.96	-1269.42	2403.24	0.45	2295.41
11th November	9.39	0.0159	0.43	429.65	196.88	1848.72	4252.40	0.79	4061.61
12th November	9.01	0.0119	0.13	133.72	-295.94	-2666.39	1586.81	0.30	1515.61
13th November	9.03	0.0079	0.09	94.43	-39.28	-354.73	1232.38	0.23	1177.08
14th November	8.81	0.004	0.00254	2.54	-91.89	-809.56	423.03	0.07	404.05
15th November	8.48	0.0000	0.000000	0	-2.542	-21.56	401.55		383.53

Table 7: Table for Net Profit and Loss

PV calculation for my cost	-22414.14
Option Payoff	0.00
Total option payoff	0.00
Final Hedge Portfolio Value	0
Premium Received	4.00
Profit/(Loss)	**-22410.14**

Delta Hedging using 22 Day Historical Volatility

Table 8: Delta Hedging using 22 Day Historical Volatility

Contract symbol	WBA241115C00009500
Short call options	10 (Assumed)
	1000 (Assumed)
Interest rate	4.70%
Strike Price	9.5

Table 9: Results for Delta Hedging using 22 Day Historical Volatility

Trade Date	Stock Price	Time to expiry (in years)	Historical Volatility	Delta	Shares owned	Shares bought/(Sold)	Cost of shares	Cumulative cost including interest	Interest cost	PV calculation for my cost including interest
5th November	9.62	0.03	0.68	0.57	570.02	570.02378	5483.62	5483.62	1.02	5483.62
6th November	9.23	0.02	0.69	0.42	428.91	-141.11	-1302.478	4182.17	0.78	3994.43
7th November	9.27	0.02	0.69	0.43	434.25	5.34	49.511	4232.464	0.78	4042.46
8th November	9.07	0.01	0.69	0.33	338.73	-95.51	-866.32	3366.93	0.62	3215.78
11th November	9.39	0.01	0.70	0.46	468.47	129.73	1218.22	4585.783	0.85	4379.92
12th November	9.01	0.01	0.71	0.26	262.90	-205.56	-1852.16	2734.47	0.51	2611.72
13th November	9.03	0.007	0.70	0.22	221.87	-41.031	-370.51	2364.46	0.44	2258.32
14th November	8.81	0.004	0.48	0.007	7.39	-214.47	-1889.53	475.37	0.08	454.03
15th November	8.48	0.0	0.43	0	0	-7.39	-62.72	412.73		394.20

Table 10: Table for Net Profit and Loss

PV calculation for my cost	26834.53665
Option Payoff	0
Total option payoff	0
Final Hedge Portfolio Value	0
Premium received	4.000000358
Profit/(Loss)	**-26830.53665**

Comparing the Implied Volatility vs the 22-day historical Volatility method

Table 11: Table comparing the IV vs 22 Day Historical Volatility

Particulars	**Implied Volatility Method**	**22-Day Historical Volatility Method**

PV calculation of cost	22414.14213	26834.53665
Payoff	0	0
Final Hedge Portfolio Value	0	0
Loss	-22410.14	-26830.53
Difference in methodology	Uses a constant implied volatility of 42.24%, representing forward-looking market expectations and sentiment.	Uses daily calculated historical volatility over the prior 22 trading days, ranging between 43.00% and 71.00%.
Delta	Delta is more reactive to market conditions due to implied volatility. Example: On November 6th, delta dropped significantly from 0.5885 to 0.3617, requiring a sale of 226 shares to adjust the portfolio. These frequent changes ensure precise hedging but lead to higher transaction volumes.	Delta changes more gradually due to its reliance on historical data, specifically a 22-day historical volatility measure. Example: On November 6th, delta decreased from 0.5700 to 0.4289, reflecting a more smoothed adjustment based on past volatility trends. This slower change in delta requires a sale of 141 shares to adjust the portfolio. While adjustments are less precise compared to implied volatility-based delta, this approach results in fewer overall transactions, reducing transaction costs over time
Cost incurred	Cumulative cost, including interest, is -22.14k slightly higher due to frequent adjustments and transactions.	Cumulative cost, including interest, is -26.53k, slightly lower because of reduced transaction volume.
Profit/Loss Comparison	Total cost is -22.14k, with no option payoff (option expires worthless). Dynamic adjustments ensure precise hedging but slightly increase costs.	Total cost is -26.53k, with no option payoff. Fewer transactions lead to marginally higher profitability in this case.
Sources of Differences	Driven by forward-looking implied volatility, allowing for real-time responsiveness to changing market conditions.	Relies on static historical patterns, which may lead to over-hedging or under-hedging if current volatility deviates.
Which Method is Better?	Best for markets with high volatility or significant price changes, as it maintains more precise hedges.	Suitable for stable markets with less fluctuation, offering simplicity and lower costs.

4. Volatility trade

This section focuses on Volatility Trade, which is a strategy that helps the trader to gain profit from changes in the volatility, instead of focusing on the price movement. It is done by measuring the magnitude of price movement of an asset over time. Higher IV suggests larger volatility and vice versa.

We observed that simple 22-day historical volatility is higher than Implied Volatility calculated using BSM and thus showing that the market predicts higher price movement in the future based on the historical average.

Table 12: Difference between Volatilities

Metric	Value
22-Day Historical Volatility	68%
Implied Volatility (IV)	42.42%
Difference	25.58%

The difference arises due to several reason such as increasing uncertainty of the market, events, since our IV calculated is lower than 22 days historical which means the traders expect a more stable market, also BSM assumes constant volatility whereas in real-world the volatility constantly changes. Lower demand for options could lead to lower IV, even if the historical volatility is high.

Strategies:

When the direction of the stock is uncertain, due to volatile markets, the **Long Straddle** is a useful tactic. Because it depends on volatility rather than directional bias, it is flexible and appropriate for situations like the one we are in right now, where implied volatility is low but is predicted to increase.

This technique involves buying both a put and call option of the same strike price (9.5) and the same expiration rate. The call option increases in value if the stock price rises significantly. The put option increases in value if it drops significantly.

Table 13: Table for Long Straddle

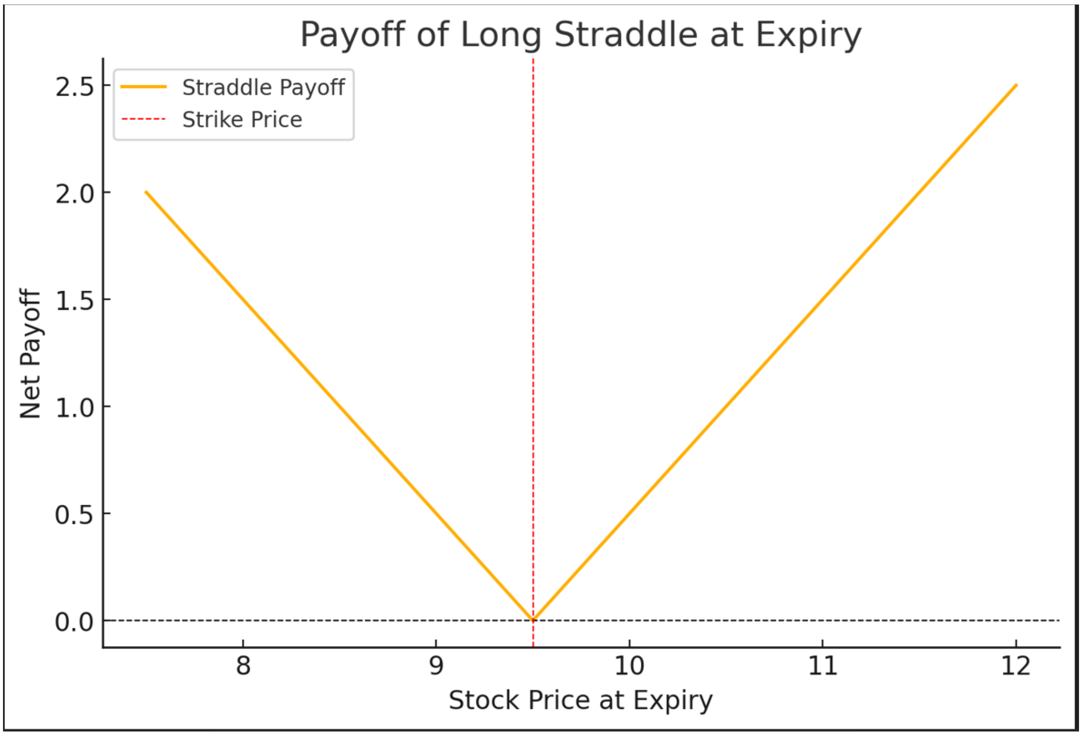
STRADDLE - ATM					
	Ticker	**Stock Price**	**K/Strike**	**Last Price**	**Payoff**
Calls	WBA 11/15/24 C9.5	9.62	9.5	0.40000004	0.12
Put	WBA 11/15/24 P9.5	9.62	9.5	0.30000001	0

Table 14: Table for Straddle Spread

Estimated Stock Price	Strike Price	Call Pay off	Put Pay Off	Total Pay Off
7.5	9.5	0	2	1.29999995
8	9.5	0	1.5	1.50000000

8.5	9.5	0	1	1.00000000
9	9.5	0	0.5	0.50000000
9.5	9.5	0	0	0.00000000
10	9.5	0.5	0	0.50000000
10.5	9.5	1	0	1.00000000
11	9.5	1.5	0	1.50000000
11.5	9.5	2	0	2.00000000
12	9.5	2.5	0	2.50000000

Figure 2: Plotting of Long Straddle



Options are reasonably priced because the IV calculated (42.42%) is much lower than the 22-day historical volatility (68%). The strategy benefits if volatility rises as anticipated because the options value grows even if the underlying price doesn't move significantly.

However, if we want to reduce our overall cost **Long Strangle** is a good alternative strategy. This technique uses out-of-the-money (OTM) call and put option with same expiration date but different strike price. We bought a call option (10.5) and put option (8.5)

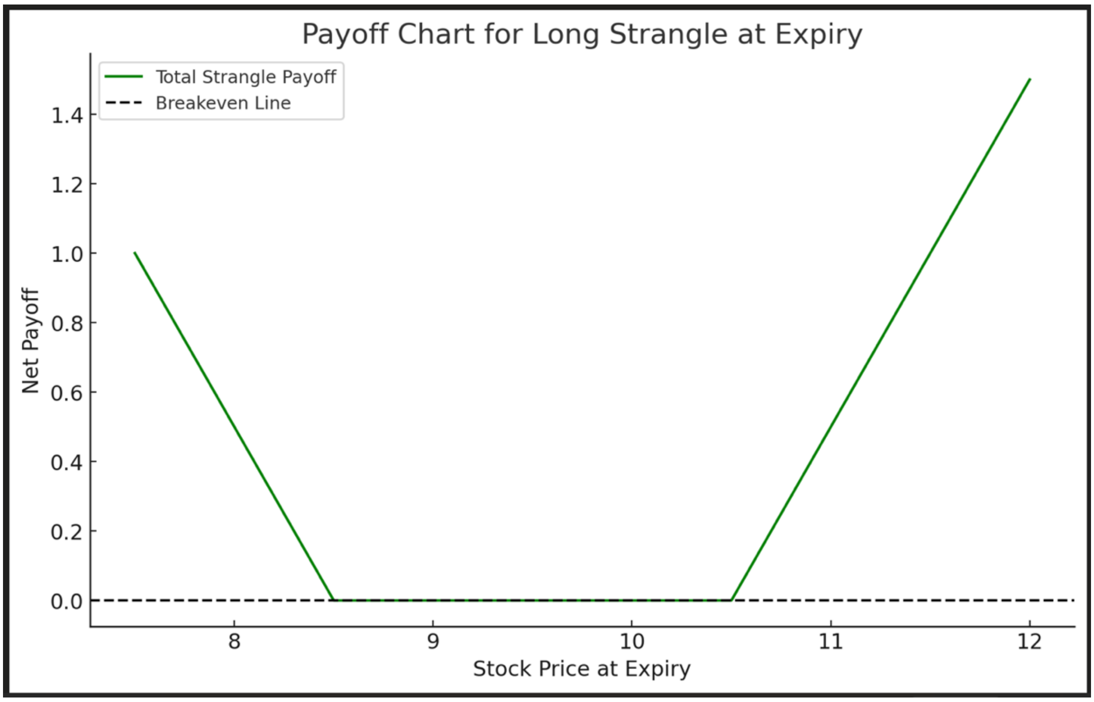
Table 15: Table for Long Strangle

STRANGLE - OTM					
	Ticker	Stock Price	**K/Strike**	**Last Price**	**Payoff**
Calls	WBA 11/15/24 C9.5	9.62	10.5	0.06999999	0
Put	WBA 11/15/24 P9.5	9.62	8.5	1.03999996	8.5

Table 16: Table for Strangle spread

Estimated Stock Price	Call Strike Price	Put Strike Price	Call Pay off	Put Pay Off	Total Pay Off
7.5	10.5	8.5	0	1	-0.11
8	10.5	8.5	0	0.5	0.50
8.5	10.5	8.5	0	0	0.00
9	10.5	8.5	0	0	0.00
9.5	10.5	8.5	0	0	0.00
10	10.5	8.5	0	0	0.00
10.5	10.5	8.5	0	0	0.00
11	10.5	8.5	0.5	0	0.50
11.5	10.5	8.5	1	0	1.00
12	10.5	8.5	1.5	0	1.50

Figure 3: Plotting of Long Strangle



Large price changes are favourable for a strangle. Strangling is a cost-effective strategy to profit from projected volatility if implied volatility is less than historical volatility and the options are reasonably priced.

This strategy is more flexible since we can adjust the approach according to our expectations of the range of volatility by selecting strike prices that are marginally above (call) and below (put) the current stock price.

Sources:

WBA Options Data	Bloomberg Terminal
Risk Free Interest Rate	Market Yield on U.S. Treasury Securities at 1-Month Constant Maturity, Quoted on an Investment Basis (DGS1MO) | FRED | St. Louis Fed
Concept References	• Series 8 Equity Derivatives – Published by NISM – National Institute of Securities Market. • Options, Futures and other Derivatives – By John C.Hull.
Graph	Excel